Selection of Rated Discharges in the Design of Small Hydroelectric Power Stations

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THE SELECTION OF COMPUTED DISCHARGES IN PLANNING SMALL GES*

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Determining the computed discharges in planning small GES is both a technical and an economical problem. However, on the basis of the computation, the discharge of a definite amount of water is adopted. This amount is ascertained on the basis of economic and technical requirements for a guaranteed supply of electric power. In accordance with the instructions of Glavsel'elektro, for kolkhoz GES a discharge of 50 percent is adopted, if there is a fuel reserve or the GES works in a common electric power system. A discharge of 75 percent is adopted when the GES works alone. It is considered that in order to make a proper selection of a discharge of a given amount, it is necessary to conduct observations over a period of not less than 5 - 10 years — the more the better — on the level of each small GES, according to N. V. Mastitskiy (2), or on a level which can be used analogously, as adopted by D. L. Sokolovskiy (6). The statistical method of processing hydrometric materials which is now widely used in the practice of hydrological engineering computations proceeds from an erroneous premise concerning the genetic uniformity of all measured discharges of water, the fluctuation of which is subject only to the law of normal distribution. On this basis, the numerical characteristics of hydrological phenomena are looked upon as being independent, accidental and changeable, while the creative work of the hydrologist in showing the interdependence of natural phenomena which make up the water cycle is replaced with

*Note: 'GES' = 'Hydroelectric (Power) Station' the mechanical selection of parameters for statistical distribution curves. Parameters are such abstract quantities as: the "norm" of flow and coefficients of variation and asymmetry. As a result of the usual short-term hydrometric observations which are made on small rivers, the norm of flow is determined by its correlative dependencies on meteorological elements or by artificially extending many observations made at other stations. The adoption of these methods often results in serious mistakes in determining the norm of flow because the fluctuation in the discharge is taken on the basis of observations of another station and other factors.

The influence of physico-geographical conditions on the formation of the flow is considered constant in time; therefore, it is studied by statistical parameters. On the basis of this, it is considered possible to use hydrological indexes obtained from observations in the past for water economy computations when planning construction works for the future.

Our investigations for determining the power resources of small rivers in Tatar ASSR show conclusively that under conditions of external objectivity statistical methods of handling hydrometric observations lead to serious mistakes in planning. Actually, the amount of the discharge of water provided at a given percentage of volume allows us to ascertain how long such a discharge will continue over a certain period of time. Economically, this amount of discharge is a fiction, since it can refer to completely different periods of the year, depending on how much water there was during the year or its seasons, and the conditions under which the spring floods and rain floods formed. For economic-hydrological reasons, it is expedient to take the August and January mean discharges as basic discharges in planning small GES. The water-supply capacity of the rivers is close to the minimum during these months: on the other hand the electric power requirements for agriculture are clearly fixed.

In August the mass gathering of the harvest begins; therefore the electric power requirements for processing agricultural products (grinding, threshing, siloing) reaches a maximum. The maximum illuminating and small-motors load peak on the kolkhozes falls in January.

Information can be obtained at the existing small GES and watermills on the water-supplying capacity of the river for those months, which are economically characteristic, by the method of hydrological photography (3), which will give the mean magnitudes of water discharge(4).

The above-mentioned considerations cause us to reject determining the computed discharges on the basis of the discharge of a given amount to be provided, which is computed from the annual cycles of observations. It will be more correct to determine the discharges of water on the basis of observations for months or seasons which are economically characteristic.

It is believed that more prolonged observations must be made possible in order to get the most reliable data. In cases where the series are notlong enough, they must include approximately the same number of wet and dry years; this should provide for a more correct determination of the mean computed discharges of water. The fallacy in the point of view which ignores the teachings of V. R. Vil'yams (1) on the water cycle of the country is confirmed by examples from the small rivers of Tatar ASSR. Regular, mass hydrometrical observations were begun on these rivers in 1931 and are continuing at present.

It has been ascertained that the water-supplying capacity of all the small rivers during these years changed sharply in the midsummer [mezhennyy] period (winter and summer).

The period from 1932 through 1940 inclusively is characterized by a progressive decrease in the water-supplying capacity during midsummer; the minimum was in 1939 - 1940.

The period from spring of 1941 to the present has been marked by a high water supply.

The data in figures 1 and 2 and Table 1 give a good illustration of the nature of the water supply by periods. They show that the water supply of different rivers changed to a different degree. While the change is not great for the Kozanka River, it is very great for the Sviyaga, Ik, and Bol'shoy Cheremshan rivers. The correct choice of the mean discharge will have a definite effect on the economic use of the rivers, since the difference between discharges is up to 300 percent and more.

To decide the question of what magnitudes of water discharge should be taken for water economy computations, it is necessary to find out what factors caused so great a change in the water-supplying capacity.

There was a general decrease in water supply in 1933 - 1944.

Many lakes dried up in the '30's. In the basin of the Ik River, the level of Lake Kordry-Kul' fell considerably (Fig 2). The shore regions of its dry bed were used as vegetable gardens in 1939 - 1940. Lake Belolebyazhye in the basin of the Sviyaga River dried up completely. Its bed was plowed and used for relocating shore villages, since the village wells ran dry.

[See Table 1, next page]

In spring of 1941 the level of the lakes began to rise. According to information from local old-timers and as can be seen from the disposition of shore structures and the position of the water table with respect to the shore slopes, Lake Belolebyazh'ye reached its "normal" level in 1949. Lake Kondry-Ku'l had not reached this level in 1948.

In many instances we have evidence that the level of the water in the wells rose 1.5 - 3.0 meters higher than in the pre-war years. This is also confirmed by data on the level of the water in the hole (Fig 2 and Table 2) located at the watershed and having no connection with variations in river waters.

TABLE 1

MEAN MONTHLY DISCHARGES OF WATER IN CUBIC METERS PER SECOND BY SMALL RIVERS FOR DIFFERENT PERIODS AT MAIN WATER-MEASURING STATIONS

Period	1933 - 1948		1933 - 1940		1941 - 1948	
River and Station	August	January	August	January	August	January
Bol'shoy Cheremshan, Melekess Station	6.34	--	2.98	--	9.70	--
Sviyaga, Vyrypayevka Station	4.73	3.40	3.18	2.32	6.29	4.64
Kazanka, Bol'shoy Derbyshki Station	4.34	3.51	4.03	3.11	4.70	3.98
Ik, Nogaybak Station	17.00	12.00	9.5	8.60	24.5	15.0
Ik, Lake Lebedinoye Station	13.0	10.1	10.0	6.89	15.5	12.1

- 5a -

TABLE 2

CHANGE IN THE WATER TABLE IN THE HOLE FOR AUGUST

Year	Table Level in Meters	Year	Table Level in Meters	Year	Table level in Meters
1939	50.20	1943	52.4	1947	52.6
1940	50.15	1944	54.0	1948	52.3
1941	51.15	1945	53.2	1949	52.1
1942	51.60	1946	52.6	1950	51.8

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Attempts to establish correlative con ections between different meteorological factors and the water-supply of rivers in the mid-summer period were unsuccessful. It was possible to determine only that the discharges of water in the midsummer period vary with the thickness of the snow covering and the magnitude of the hydrothermic coefficient (Fig 2). This occurred because the snow covering indicates how deep the soil freezes, and is therefore an index of its infiltration capacity, while there is a good correlation between the hydrothermic coefficient and the moisture of the soil which serves as an indirect criterion of the loss of ground waters through evaporation and transpiration.

According to data from supporting meteorological stations located at points having different physico-geographical conditions, the climatic conditions for the entire territory were almost the same; periodically they changed simultaneously and to a very small degree (Table 3).

[See Table 3, next page]

Comparison of tables 1 and 3 leads to the conclusion that there is no correspondence between the change in precipitation, increasing 25 - 30 percent, and the increase in water supply, which, for various rivers, changed from 25 to 400 percent. This circumstance leads us to propose that not only the amount of precipitation changed, but the conditions of infiltration as well.

Soils, according to V. R. Vil'yams, are the product of climate, but recent soils are the product of labor. V. R. Vil'yams

TABLE 3

PERIODIC CHANGES IN METEOROLOGICAL CONDITIONS FROM THE

NORM IN PERCENTAGES

Station	Total of Mean Monthly Temperatures				Hydrothermic Coefficient for June and July		Thickness of Snow Cover		Total Annual Precipitations	
	Negative		Positive							
	1933 - 1940	1941 - 1948	1933- 1940	1941- 1948	1933- 1940	1941- 1948	1933- 1940	1941 - 1948	1933- 1940	1941 - 1948
Bugul'ma	96	100	108	95	96	144	70	85	75	112
Ul'yanovsk	97	100	106	98	63	130	80	90	80	105
Kazan'	92	98	109	98	73	134	70	84	77	103

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up the pores between the clods of soil. When plowed to the surface this humus impeded the infiltration of thaw water. Under the action of the natural soil-formation process and, chiefly, because of the correct and complete use of agrotechnical measures by the kolkhozes, the structure of the soils gradually improved.

In 1941 a new factor was added -- favorable meteorological conditions, which influenced the water supply to rivers in the midsummer period. The increase in the water supply to rivers cannot be explained only by the change in meteorological conditions, because the discharges of the rivers increased 200 - 600 percent while the precipitation increased only 30 - 40 percent.

In the period from 1941 - 48 the midsummer discharges had rather stable, high waters, which were promoted by an increase in the thickness of the snow cover (70 - 80 percent of norm) and a decreased loss through transpiration and evaporation, thanks to the increase in size of the hydrothermic coefficient in the summer period (130 - 140 percent of norm).

Soil conditions in 1941 - 49 were favorable for infiltration. In 1942 a considerable number of arable lands were removed from field crop rotation and put to use as natural pasture lands for cattle grazing. In accordance with V. R. Vil'yams ideas, there was also a replacement of cultivated plants with wild ones-- a substitution by no means accidental -- and an absolutely regular development of weed and grass fallows, characterized by deep changes in the structure of the soil covering favorable to increasing infiltration. Part of these lands were then once more put to use in field crop rotation and other sections removed. In this way there was further improvement of the structure of the soil on large areas of arable lands. These improvements have continued to have favorable effects right up to the present time.

Our investigations of underground feeding of small rivers have shown that in most cases they are fed in the midsummer period by the upper water bearing table and that the feeding region coincides with the drainage region. Feeding from the water-bearing tables takes place simultaneously along a considerable extent of the midstreams [mezhdurechue] when the spring snows thaw. The water-bearing tables discharge and drain only along the boundaries of the river system. As a result there is at the same time an increase in the reserves of ground waters, and the underground feeding into the rivers, which was observed in 1941 and 1944, commences (Fig 1 and 2).

The discharge of the ground waters is at first most intensive in the river bed region; then the watersheds begin to take part in feeding the rivers. The process of draining takes place slowly because of the low speed of ground water circulation. Therefore, the midsummer discharges are not essentially influenced by particular meteorologically unfavorable years. Only for regions in which the feeding areas and the discharging area of the water-supplying tables do not coincide is the opinion held by B. V. Polyako(5) and A. N. Semikhatov just. They believe in the possible decrease of underground feeding in the first year in which agrotechnical measures were used, field grass crop rotation introduced, and timber belts planted.

In connection with this there arises the question of the nature of the following years which were characterized by low water supply. Let us look over the meteorological data for 1931 - 1940 (Table 4).

[See Table 4, next page]

The meteorological conditions over this 10-year period were unfavorable for the formation of midsummer discharges, which had been unusual for the past 70 years. They coincided in time with as many unfavorable soil conditions, and the two together explain the low water supply to rivers during the midsummer period. Since identical conditions cannot repeat in the future, these conditions provide no basis in water power computations for computing the discharges of water for 1931 - 1940.

After the considerable exhaustion of the water-bearing table observed in 1931 - 40, meteorological and soil conditions in the next 10 years (1941 - 1949) approached the "norm". The mean discharges of water for this period should be used as a basis for hydrological computations in planning GES, because they represent a probable mean progressive magnitude (8) of river discharges in the past years.

In the future the development of soil formation processes will receive more guidance through the complex measures undertaken in connection with Stalin Plan for the Transformation of Nature. The creation of timber belts, the introduction of grass crop rotation, and the building of ponds and reservoirs will in

TABLE 4

VARIATIONS IN METEOROLOGICAL FACTORS (IN PERCENT) FROM THE MEAN MAGNITUDES FOR THE ENTIRE PERIOD

Period	Total Precipitation					Total Temperature		Hydrothermic Coefficient for June and August	Thickness of Snow Cover	Mean Temperatures of air for June and August
	Entire Year	Winter	Spring	Summer	Autumn	Negative	Positive			
1892 - 1900	97	89	89	105	102	113	106	102	100	95
1901 - 1910	100	107	94	105	85	103	97	108	112	102
1911 - 1920	105	122	108	94	97	96	96	94	122	103
1921 - 1930	106	112	86	98	129	88	99	92	110	92
1931 - 1940	86	78	104	79	98	92	105	78	68	106
1941 - 1949	105	87	118	123	86	105	95	124	87	101

the next few years create conditions favorable to infiltration by surface waters, and ultimately to increased moisture turnover in the atmosphere. The irrigation of land massifs in the southeast USSR will also help increase moisture turnover.

Undoubtedly, the river discharges during the midsummer period will increase.

In the near future the mean discharges of rivers will even appear somewhat lowered, if we accept them as identical with the actual discharges in 1941-49.

In the case of individual rivers the amount of water-supply will be conditioned by local physico-geographical peculiarities in the formation and draining of underground waters in their basins (tables 1 and 5).

Considerable surface slope, the great density of the river and ravine network, structureless podzol soil with underlying clays and argillaceous soils previously predominated in the Kazanka River basin. All this creates favorable conditions for an increase of surface flow and a decrease of infiltration. The high moduli for the midsummer discharges are explained by local discharge of head waters forming behind the boundaries of the basin (3).

The Ik River basin, on the other hand, is predominantly composed of permeable, thin layers of chernozem soils with underlying crumbling marls from the Tatar stage. Thanks to this, a large part of the atmospheric precipitation infiltrates, and the river network during the midsummer is fed by local discharge waters from the upper water-bearing table, whose discharge is subject to wide variations. The influence of the soil factor and the porous underlying layers is so great that despite the many slopes the surface flow is small. This explains, too, the negligible development of the ravine network.

In the Bol'shoy Cheremshan basin the conditions for the infiltration of atmospheric precipitation are also favorable. Almost all the podzol soils are found under forest massifs. Very slight sloping of the ground surface and poor development of the river and ravine network predominate. The Sviyaga River basin has the same conditions. Both basins are characterized by a thin layer of spring discharge; this is explained by the very great losses of the thaw dischar e through infiltration. The great difference between the moduli of the midsummer discharges of water in these basins and their individual variability (Table 1) is explained by the drainage conditions of the underground waters, the differing depths of the valleys shaped by erosion, and the nature of the incline of the water-bearing table with respect to the river beds.

The river network of the Sviyaga River drains almost all the underground waters in the region above Vyrypayevka. Although the general incline of the water-bearing table has a direction opposite to the progression of the river network, the many local elevations create conditions favorable to draining.

[See next page for Table 5]

The river system of the Bol'shoy Chermshan is located on a

TABLE 5

Basic Factors in the Nature of the River Basins

Water Measuring Station	Area of the Basin under Different Soils, in Percent		Coefficient of Density of Net-Work KX 100		Distribution of Slopes of Ground Surface in Percentage		Timber-land in Percentage**	Ratio in Mean Discharge 1941 - 1948 to Discharge 1932-1940 in Percentage	Layer of Spring Discharge in Millimeters*
	Chernozem*	Podzol**	River*	Ravine**	To 0.03	0.03 - 0.06			
Melekess	57	30	24	6	90	8	24	304	40
Vyrypayevka	66	17	18	19	89	8	22	195	30
Bolshaya Derbyshka	--	90	31	44	66	32	11	122	100
Nagoybak	87	13	34	6	59	23	12	236	60
Lake Lebedinoye	--	96	40	6	77	22	36	183	80

* Determined by Ye. M. Zinov'yeva

** Determined by Ye. M. Zinov'yeva and G. N. Petrov for all the rivers in Tatar ASSR.

relatively steep monocline and the cut of the valley by erosion is not very deep. The direction of the river network and the water-bearing table is the same. This leads us to the conclusion that large masses of underground waters are not drained by the local river network, but are led off beyond its basin.

The data set down here explain the reason for the change in the water supply of rivers and show that one cannot judge the water supply and its variations in other rivers on the basis of data from one river.

CONCLUSIONS

1. The mean discharges of rivers for engineering-hydrological planning of small GES cannt be determined by using all available hydrometric observations for individual seasons or for the entire year's cycle based on a given percentage of supply. Computation done in this manner would result in a false quantity not suitable for the needs of the national economy.

2. Of the many available observations, only those should be chosen which closely approximate the changing meteorological and soil conditions in the formation of midsummer discharges at the time when these hydrological installations will operate.

3. For the small rivers of Tatar ASSR and adjoining territories, the mean midsummer discharges of water for the period from 1941 - 49 are more accurate than the mean progressive water cycle quantities established with the realization of the Stalin Plan for

the Transformation of Nature.

4. The midsummer discharges of rivers for 1932 - 1940, which are not characteristic of future meteorological and soil conditions should not be taken into account when planning for hydrological engineering installations from hydrological point of view.

5. The determination of the coefficients of variation and asymmetry of all the many available observations is of no practical interest. Extreme values of water discharges should be determined from an analysis of the possible change in the physical-geographical conditions in the formation of underground feeding. These meanings should be determined on the basis of hydrological-hydrometrical investigation by the hydrological photography method (3,4) and not by the method of mathematical statistics which results in abstract, actually unfounded amounts.

6. Many, many hydrometric observations are necessary for the correct choice and evaluation of characteristic periods, because "true science, based on a study of the essential qualities of processes, turns to the past only for the purpose of studying the development of the process in its historical perspective". (Vil'yams)

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E N D

APPENDIX [see page 17 for thermoprints]

Lake Lebedinoye Station

Izh River

Nogaybak Station

Ik River

Vyrypayevka Station Sviyaga River

Figure 1. Variation in the mean Monthly Discharge of Rivers

Figure 2. Change in the Water-supplying capacity of rivers depending on meteorological factors.

A - Kazanka River, Bol'shaya Derbyshki Station, Arsk Meteorological Station; B - Ik River, Nogaybak Station, Bugul'ma Meteorological Station; C - Sviyaga River, Vyrypayevka Station, Ul'yanovsk Meteorological Station. a - modulus of discharge for August in liters per second per square kilometer; b - modulus of discharge for January in liters per second per square kilometer; c - hydrothermic coefficient for June-August; d - total annual precipitation in millimeters; e - thickness of snow cover in centimeters; f - variation in water level of hole at watershed; g - variation in watershed of Lake Kondry-Kul', according to data from water-measuring station (broken line -- according to information from inhabitants).

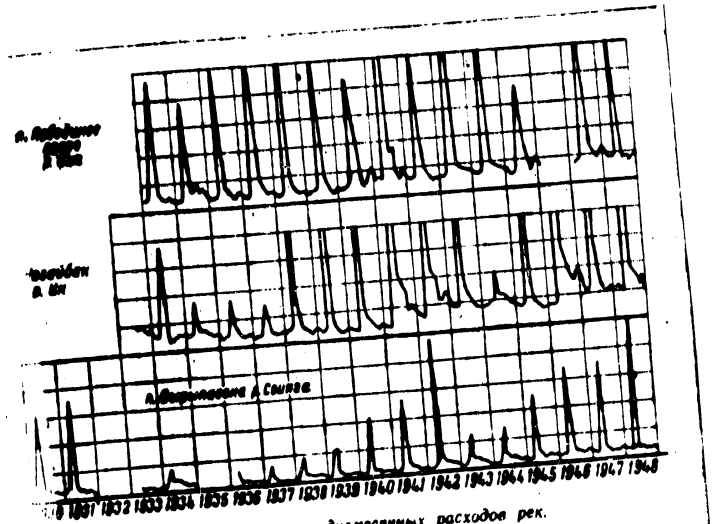

Рис. 1. Колебание среднемесячных расходов рек.

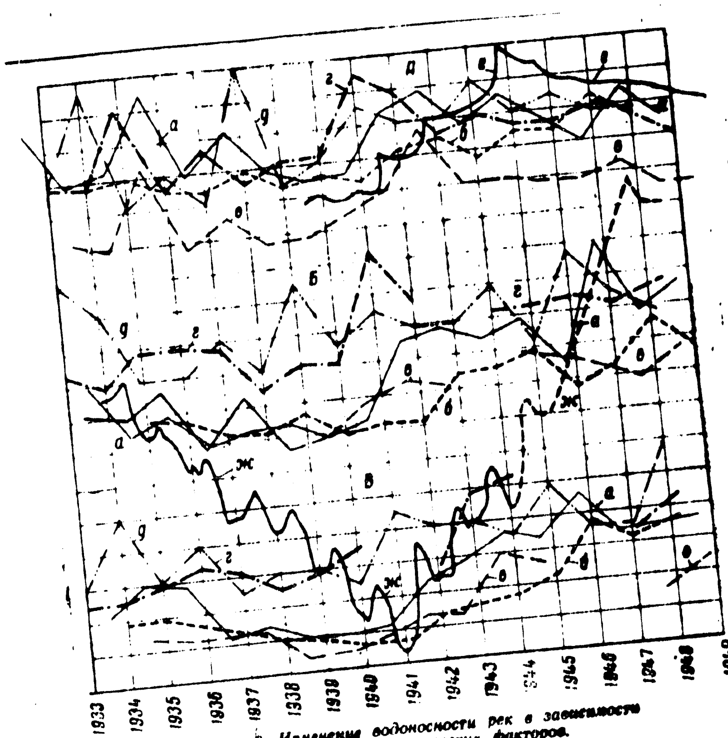

Рис. 2. Изменение водоносности рек в зависимости от метеорологических факторов.

А — р. Казанка, п. В Дербышки, метеостанция Арск; Б — р. Ик, п. Ногайбак, метеостанция Бугульма; В — р. Свияга, п. Вырыпаевка, метеостанция Ульяновск. а — модуль расхода августа в л/сек./км²; б — модуль расхода января в л/сек./км²; в — гидротермический коэфициент за июнь-август; г — сумма осадков за год в мм; д — толщина снегового покрова в см; е — колебание уровня воды скважины на водоразделе; ж — колебание уровня воды оз. Кондры-Куль, по данным водомерного поста (пунктар — по сведениям жителей).

— END —

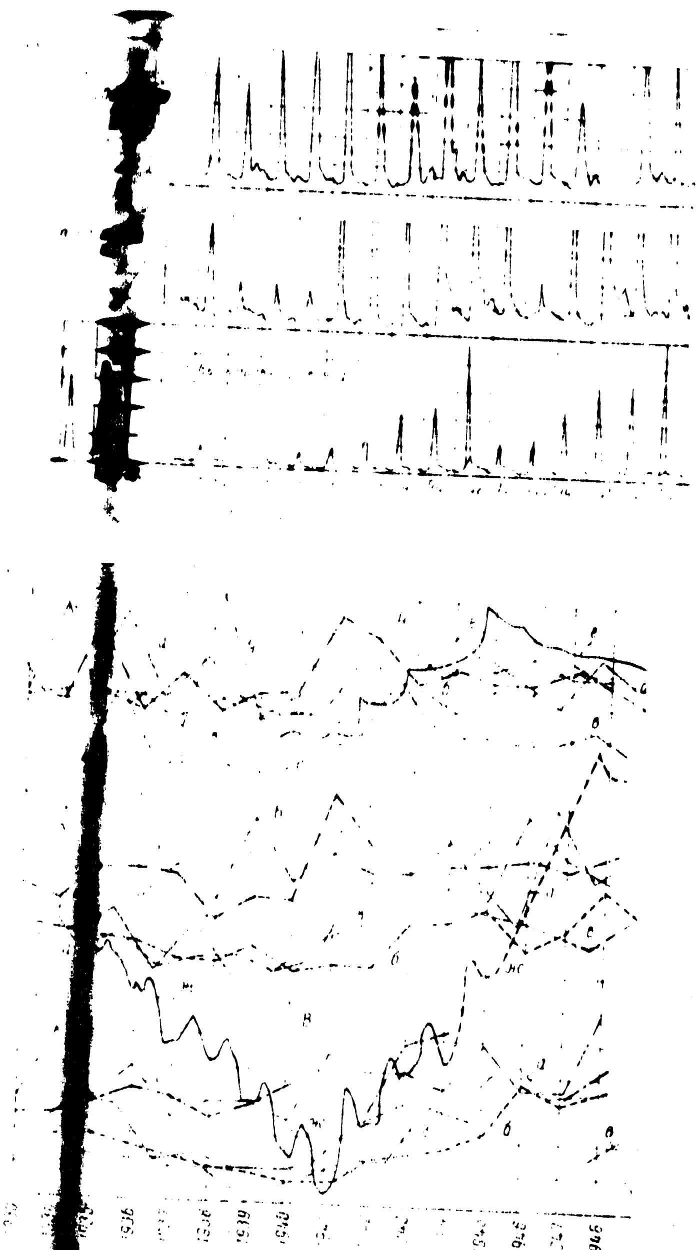

Рис. ... Изменение ... зависимости от метеорологических факторов

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